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Applicant:	Marc Bolduc et al.	Examiner:	N/A
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Title:	DISPLAYING IMAGE DATA		

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COMMUNICATION REGARDING PRIORITY DOCUMENT

Commissioner for Patents
Washington, D.C. 20231

Dear Sir:

Please place the following Certified Priority Document into the file of the above-identified patent application, as follows:

UNITED KINGDOM, Serial No. GB/01/09/621.3, Filed on April 19, 2001

Respectfully submitted,

Marc Bolduc et al.

By their attorneys,

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Dated 14 June 2001

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Request for grant of a patent
Grant

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1.	Your reference	19 APR 2001 2034-P562-GB
2.	Patent application number	0109621.3 New
3.	Full name, address and postcode of the or of each applicant *(underline all surnames)*	DISCREET LOGIC INC 10 Duke Street Montreal, Quebec Canada H3C 2L7 6972319002
	Patents ADP number *(if you know it)*	
	If the applicant is a corporate body, give the country/state of its incorporation	Quebec, Canada
4.	Title of the invention	Displaying Image Data
5.	Name of your agent	ATKINSON BURRINGTON
	"Address for service" in the United Kingdom to which all correspondence should be sent	25-29 President Buildings President Way Sheffield S4 7UR GB
	Telephone No:	0114 275 2400
	Patents ADP number	7807043001

		Country	Priority application number *(if you know it)*	Date of filing *(day/month/year)*
6.	If you are declaring priority from one or more earlier patent applications, give the country and the date of filing of the or of each of these earlier applications and *(if you know it)* the or each application number	N/A	N/A	N/A

		Number of earlier application	Date of filing (day/month/year)
7.	If this application is divided or otherwise derived from an earlier UK application, give the number and the filing date of the earlier application	N/A	N/A

8.	Is a statement of inventorship and of right to grant of a patent required in support of this request?	Yes

9. Enter the number of sheets for any of the following items you are filing with this form. Do not count copies of the same document

Continuation sheets of this form	
Description	21
Claim(s)	08
Abstract	01
Drawings	13 + 13

10. If you are also filing any of the following, state how many against each item.

Priority documents	N/A
Translations of priority documents	N/A
Statement of inventorship and right to grant of a patent (*Patents Form 7/77*)	None
Request for preliminary examination and search (*Patents Form 9/77*)	One
Request for substantive examination (*Patents Form 10/77*)	None
Any other documents (*Please specify*)	

11. I/We request the grant of a patent on the basis of this application.

Signature

Date **Wednesday, 18 April 2001**

12. Name and daytime telephone number of person to contact in the United Kingdom

RALPH ATKINSON CPA
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LA-04-058

Displaying Image Data

Background of the Invention

1. Field of the Invention

The present invention relates to viewing image data over a network, and in particular relates to viewing a clip of image frames on a viewing station connected to a network over which the image data is transmitted.

2. Description of the Related Art

Computer networks are used to transfer data of many kinds. Text data does not present much of a problem for today's networks. However, streams of media data, such as continuous sound and images, easily create problems for networks. The difficulty with media data is twofold: firstly, there is a lot of it, and secondly, it is usually desirable to listen to or view the data in real time as it is being transferred.

Both these requirements can be eased by the use of data compression, and it is in this area that attempts to satisfy these requirements are most numerous. In particular, developments in the MPEG video format have enabled streaming of reasonable quality audio and low quality video, over the Internet, even when the connection is made by a telephone line and has a low bandwidth. The widespread adoption of compression standards has introduced audio and video to the home computer, upon which it is now possible to assemble and composite home movies of increasing duration and quality.

Professional digital image processing encompasses both video and, increasingly, high quality film editing. The amount of data in a single frame of

film can be as much as forty megabytes. Such frames need to be processed and or viewed at a rate of twenty-four frames per second, resulting in extremely high requirements for both data transfer and data processing. Often such transfers cannot be performed in real time over a network, either because the network has too low a bandwidth, or because network traffic is prohibitive. The problem in these high-end systems is the same as in general purpose computing, and it is only a matter of scale.

Data compression can be used to minimise the difficulty of supplying media data over a network, whether that be a high speed specialised video data network, or the Internet. The particular problem that remains is one of predictability: one may choose a level of data compression that seems likely to result in a sustainable reception of the media data, but this is a fixed assumption, and network capacity will vary from second to second. A fixed data rate will always either overestimate or underestimate the capacity of the network, which is forever changing.

In the art, the solution to these requirements is buffering. By fetching a few seconds' worth of media data before it is rendered, two systems are invoked: a prefetch system and a playback system. The prefetch system is a looped set of instructions to transfer as much data as possible into a memory buffer until the buffer is completely full. The playback system is a looped set of instructions to read from the buffer and render the data in real time. While the prefetch loop can vary in speed according to the conditions of the network, the playback rate is fixed. By providing a sufficiently long buffer, intermittent poor performance of the network will be compensated by peaks in data transfer, while playback will always be able to proceed at a constant rate, and generate output in real time, albeit with a constant delay.

The restriction with this approach is that it still makes an assumption about the average rate of data transfer over the network. The inaccuracy of such an assumption can be compensated by using longer buffers. This is why media playback over the Internet is usually preceded by several seconds of inactivity, perhaps several minutes, while the playback buffer is initially filled.

In the specialised world of video and film editing, the ability to preview a clip of image data over a network is valuable. While working on the compositing of a new film, several clips will be located remotely on a frame store. The operator of an image processing station will not wish to transfer a clip over the network unless she is certain that it contains the material she is intending to work on. Transferring the clip can take a lot of time, so it is often required that a preview is made first. However, even a quick preview can result in network capacity being exceeded, especially when there is a lot of traffic. Alternatively large buffers can be used, possibly requiring several minutes to fill, thus making the preview process less worthwhile, compared to simply loading the whole clip and viewing it once all the image frames are locally accessible.

Brief Summary of the Invention

According to a first aspect of the present invention, there is provided apparatus for viewing image data, comprising display means, processing means and network connecting means for transferring frames of said image data over a network from a remotely connected frame source; said image data comprises a plurality of image frames, and has a frame rate from which may be inferred a due time for display of each frame in a sequence of frames

in said image data; said frame source returns a frame in response to a frame request issued over said network; wherein said processing means is configured to play a clip by: displaying selected frames from said frame source, on said display means, at their due time; and skipping frames in said frame sequence in response to an indication of the data transfer rate of said network

Brief Description of the Several Views of the Drawings

Figure 1 shows a network with an image processing station and a frame store, the image processing station including a monitor and a processing system;

Figure 2 details operations performed by a user of the image processing station shown in *Figure 1*, including a step in which a clip is previewed;

Figure 3 details a view on the monitor shown in *Figure 1*;

Figure 4 details components of the processing system shown in *Figure 1*, including processors and a main memory;

Figure 5 details the contents of the main memory shown in *Figure 4*, as they would appear during the preview step shown in *Figure 2*, including player instructions;

Figure 6 summarises steps performed by the processors shown in *Figure 4* when executing the player instructions shown in *Figure 5*, including a step of waiting for the user to end playback;

Figure 7 summarises threads operating during playback of a clip that are active during the step of waiting for a user to end playback shown in *Figure 6*, including a prefetch thread and a playback thread;

Figure 8 summarises the invention, including details of the prefetch thread and the playback thread shown in *Figure 7*, and including steps of prefetching another frame, displaying a frame and synchronising prefetch;

Figure 9 details the step of prefetching another frame shown in *Figure 8*;

Figure 10 details the step of displaying a frame shown in *Figure 8*;

Figure 11 details the step of synchronising prefetch shown in *Figure 8*, including a step of updating the skip rate;

Figure 12 details equations relating to the step of updating the skip rate shown in *Figure 11*; and

Figure 13 details the step of updating the skip rate, shown in *Figure 11*.

Best Mode for Carrying Out the Invention

The invention will now be described by way of example only with reference to the accompanying drawings.

Figure 1

A system for processing image data is shown in *Figure 1*. A first image processing station **101** comprises a processing system **102**, a monitor **103**, a keyboard **104** and a graphics tablet **105**. The processing system **102** is configured to perform operations for the editing and viewing of image clips. A clip comprises a sequence of image frames that are displayed on the monitor **103** at a regular rate, depending upon the format of the clip that is being played. Several standards are known, notably NTSC, which has a frame rate of thirty frames per second, PAL, which has twenty-five frames per second,

and cinematographic film, which usually has a playback rate of twenty-four frames per second. The resolution of the frames affects the amount of data that needs to be transferred in order to view a clip at its required rate.

Editing of clips is increasingly performed using digital processing equipment as shown in *Figure 1*. Instructions for image processing may be installed on the processing system **102** from a CDROM **111**, or alternatively by file transfer over the Internet. Once the image application instructions are installed, a user at the image processing station **101** is able to combine several pre-recorded clips together, apply effects, crossfades, color adjustments and so on, in order to generate a fully finished work, in the form of image data for broadcast or use in part of a film. In the system shown in *Figure 1*, the first image processing station **101** is connected to a network **106**, over which image data may be transferred. A second image processing station **107** and a third image processing station **108** are also connected to the network **106**, and these may be configured to perform similar functions to those of the first image processing station.

Image data is stored remotely in a frame store **109**. The frame store comprises a number of hard disk drives, connected together in a RAID (Redundant Array of Inexpensive Disks) configuration. This configuration facilitates high storage capacity, high reliability and high access speed for the image data. Additional frame stores may be located at each of the image processing stations, depending upon the nature of the work that is to be done. The frame store **109** is connected to a second processing system **110**, through which image data is transferred to and from the network **106**, and thereby to the connected image processing stations.

In a typical workflow, the user of the first image processing station edits a clip of image data. However, before editing can commence, it is necessary for the user to download the clip from the frame store **109**. Sometimes the user will need to browse several clips, or sections of a long clip, before the required image data can be identified. In many cases, the amount of data contained in a clip will put a severe strain upon the network **106**. Several image processing stations are connected to the network **106**, and so the problem of network transfer is made worse by the unpredictable nature of network traffic.

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Figure 2

The workflow of a user at the first image processing station **101** is summarised in *Figure 2*. At step **201** the user switches on the processing system **102**. At step **202** the user can, if necessary, install the image processing instructions, including player instructions. The player instructions may be installed separately, for example as a plug-in. Instructions may be installed from CDROM **111**, the Internet, or over the network **106** from another processing station. At step **203** the image processing instructions are started. At step **204**, the user previews a clip from the frame store **109**, using the clip player. When the clip player is in use, the image processing station is performing the function of a viewing station, which in another embodiment may take the form of a personal digital assistant (PDA) connected to a wireless network, for example.

At step **205** the user may continue with more image processing, or alternatively, once all image processing is complete, this step finishes the workflow.

Figure 3

When the user instructs the processing system **102** to execute clip player instructions at step **204**, a window containing the player's user interface is displayed upon the monitor **103**. The player's appearance on the monitor **103** is detailed in *Figure 3*. The player **301** includes a rewind control **302**, a reverse play control **303**, a stop control **304**, a forward play control **305** and a fast forward control **306**. A timecode display **307** indicates the timecode for the currently displayed clip frame. Several text fields are provided **308** for the selection of different clips in the frame store **109**, and for facilitating start of play from any frame within a clip.

Controls for selecting a skip rate are shown at **309**. In the present embodiment, the skip rate may be selected as being automatic, 2:1 or 3:1. The skip rate may be set by the user, or automatically by the player, in order to facilitate optimal playback of a clip over the network **106**. The clip images are displayed in a window **310** of the player.

When the user previews clips on the player, frames are always displayed at their correct time, and this is achieved by skipping some frames when this becomes necessary. Regardless of the data capacity of the network, a clip having a duration of one minute will always complete playback in one minute. The user will therefore see all actions portrayed in the clip take place with their timing preserved. A loss of network bandwidth availability will only result in a degradation in smoothness of action, not a modification of the rate at which the recorded events unfold.

Figure 4

The processing system **102** shown in *Figure 1* is detailed in *Figure 4*. The processing system **102** is an Octane™ produced by Silicon Graphics Inc. It comprises two central processing units **401** and **402** operating in parallel. Each of these processors is a MIPS R12000 manufactured by MIPS Technologies Incorporated, of Mountain View, California. Each of these processors **401** and **402** has a dedicated secondary cache memory **403** and **404** that facilitate per-CPU storage of frequently used instructions and data. Each CPU **401** and **402** includes separate primary instruction and data cache memory circuits on the same chip, thereby facilitating an additional level of processing improvement. A memory controller **405** provides a common connection between the processors **401** and **402** and a main memory **406**. The main memory **406** comprises two gigabytes of dynamic RAM.

The memory controller **405** further facilitates connectivity between the aforementioned components of the processing system **102** and a high bandwidth non-blocking crossbar switch **407**. The switch makes it possible to provide a direct high bandwidth connection between any of several attached circuits. These include a graphics card **408**. The graphics card **408** generally receives instructions from the processors **401** and **402** to perform various types of graphical image rendering processes, resulting in images, and clips being rendered in real time on the monitor **103**.

A SCSI bridge **410** facilitates connection between the crossbar switch **407** and a DVD/CDROM drive **411**. The DVD/CDROM drive provides a convenient way of loading large quantities of data, and is typically used to install instructions for the processing system **102** onto a hard disk drive **412**. Once installed, instructions located on the hard disk drive **412** may be

transferred into the main memory **406** for execution by the processors **401** and **402**. An input output (I/O) bridge **413** provides an interface for the graphics tablet **105** and the keyboard **104**, through which the user interacts with the processing system **102**. A second SCSI bridge **414** provides an interface with a network card **102**, that facilitates a network connection between the processing system **102** and the network **106**.

Figure 5

The contents of the main memory **406** shown in *Figure 4*, as they would appear during step **204** in *Figure 2*, are detailed in *Figure 5*. An operating system **501** provides common system functionality for application instructions running on the processing system **501**. Preferably the operating system **501** is the Irix™ operating system, available from Silicon Graphics Inc. Included with the operating system instructions, are instructions **502** for making a data transfer over the network **106**. Application instructions **503** include instructions for clip editing and effects processing. Included with the application instructions are player instructions **504**.

Memory contents **501** to **504** comprise instructions and static data components that define how the processing system **102** operates. In addition to these components, are dynamic memory contents **505** to **507**, whose constituents change as a result of instruction execution upon the processors **401** and **402**. A frame queue **505** is created by the player instructions **504** in order to temporarily store frames that have been prefetched from the frame store **109** during playback. Prefetch parameters **506** determine which frames are to be fetched into the frame queue **505**. Other data **507** represents all other data used by the operating system and applications running on the

processing system **102**.

Figure 6

Steps performed by the processing system **102** during step **204** in *Figure 2*, in which a clip is played, are detailed in *Figure 6*. At step **601** the user operates the keyboard **104** and or graphics tablet **105** to interact with the player **301**, to define which clip to play. The user may also set a start frame or time anywhere within the clip from which playback will begin. The user can also set the skip rate **309** to "automatic", "2:1" or "3:1". At step **602**, a prefetch thread is started. This results in there being two concurrent threads of execution: the prefetch thread and the main thread of execution.

The prefetch thread is a process that independently fetches frames from the frame store **109** via the network **106**. The frames are stored into the frame queue **505**, which has a fixed length of eight frames.

At step **603** the main thread of execution examines the state of the frame queue, waiting until all eight frames have been prefetched before playback begins. At step **604** a player thread is created. This thread reads frames from the frame queue **505** and displays them in accordance with the time at which they are intended for display.

The main thread of execution waits at step **605**, until the user performs an action that stops playback, for example, clicking on the stop button **304**. When playback ends, both the prefetch thread and the player thread are stopped. At step **606** a question is asked as to whether the user wishes to play another clip, or perhaps the same clip from a different start point. If so, control is directed back to step **601**. Alternatively this completes the steps performed while viewing a clip using the player **301**.

Figure 7

The prefetch thread and the player thread are both executed concurrently during step **605** of *Figure 6*. This is illustrated by *Figure 7*. Although the two threads may be considered as separate simultaneous processes, they share access to the frame queue **505** and the prefetch parameters **506**.

A clip comprises multiple frames of image data that are intended to be viewed on a screen at regular intervals, for example at a rate of thirty frames per second. Knowledge of the frame rate implies a due time for display of each frame within the clip. Due time of a frame, and the frame rate for a clip, are both examples of a frame timing parameter. If the clip is to be played back from a frame different from the first frame of the clip, then this may be taken into account, and a different set of due times is implied for each of the frames that are displayed during a playback. A convenient unit of time for a clip is the frame, and, in combination with the frame rate parameter, this can be used to provide all the timing information about a clip that is necessary for correct timing of playback.

In addition to playing back frames from the frame store **109**, frames may be rendered remotely by a rendering process running on a remote processing system **109**, each frame being rendered in response to a request for a frame from the image processing system **101** on which the player **301** is running. The frames created in this way may be considered as a frame source, from which a clip may be viewed. For the purposes of the present embodiment, a clip is any sequence of image frames intended for display at regular intervals. The Internet is a suitable network for the transfer of image

data to the player, and an advantage is obtained over known techniques of the art, given that the rate of data transfer over the Internet is highly unpredictable.

Figure 8

The invention is summarised in *Figure 8*. In this Figure, both the prefetch and the player threads are detailed, at **701** and **702** respectively. The prefetch parameters 506 form a link from the player thread **702** to the prefetch thread **701**. The prefetch parameters include a skip rate, SR, **801** and a next frame to prefetch, NP, **802**. The prefetch thread **701** writes frames to the frame queue **505**, and the player thread **702** reads frames from the queue **505** at their due time. The skip rate, SR, causes the prefetch thread to skip frames within the sequence of frames in a clip. In this way, the overall bandwidth required for clip playback is reduced, but each frame in the queue is still displayed at its correct due time, thus maintaining the timing integrity of the clip.

The frame queue **505** has an in-pointer **803** and an out-pointer **804**. The queue is eight frames long, and is arranged as a circular buffer. In the example shown in *Figure 8*, frame numbers **144**, **146** and **148** have already been displayed, and the out-pointer **804** indicates frame number **150** as being the frame currently on display. As the player thread **702** reads frames from the queue **505**, the out-pointer **804** will advance through frames **150**, **152**, **154** and so on, while the in-pointer will advance with new frames **160**, **162**, and so on, assuming that the skip rate remains unchanged from its value of two. The in-pointer and out-pointer can advance at different rates: the out-pointer is under control of the player thread, which displays frames in

accordance with a match between the due time of a frame, and the elapsed real time since playback started. The prefetch thread fetches frames according to the skip rate, and so the in-pointer **803** advances according to the relation between the amount of data transferred, and the data bandwidth available for transfer over the network.

It is possible for the queue **505** to run out of frames ready for display, if the out-pointer catches up with the in-pointer. This happens if the skip rate is set too low. The skip rate may be increased manually, to 3:1, or alternatively an automatic mode can be selected, which adjusts the skip rate in accordance with a constantly updated measurement of the network data transfer rate.

The prefetch thread **701** comprises two main steps. At step **811** a question is asked as to whether the frame queue **505** is already full. If so, no action is taken, and this question is repeated until there is room for a new frame in the queue **505**. At step **812** another frame is prefetched. The frame number of the next frame is given by the prefetch parameters, one or both of which, may have been updated by the player thread **702**. Having prefetched another frame at step **812**, control is directed back to step **811**.

The player thread **702** comprises two main steps. At step **821** a frame is displayed at its due time. New frames are not always displayed, as it is often the case that the frame already on display is the one that is most appropriate for the current state of elapsed real time. At step **822** the prefetch thread is synchronised by updating one or several prefetch parameters **506**. After step **822**, control is directed to step **821**. Synchronisation, as used in this description, means the attempt to ensure synchronous movement of the in-pointer and the out-pointer of the frame queue, such that neither overtakes

the other, and a constant gap of several new frames is maintained. The prefetch parameters control the amount of data that is transferred, so that the player thread **702** can display new frames as frequently as possible, but always at their correct due time.

The clip player **301** is optimised for the best possible smoothness in accordance with the changing data transfer capacity of the network, while maintaining the timing integrity of the clip. So, for example, a clip that lasts one minute ten seconds, will play back in that time, even though the network transfer rate may changes dramatically throughout playback. During playback, the smoothness changes because frames are being skipped to a greater or lesser extent, but the timing of events depicted in the clip, is preserved.

The implementation of steps within the two threads **701** and **702** may be varied according to implementation. It is possible, for example, to use only a single thread, but with a more complex allocation of processing time for the central processors **401** and **402**. Alternatively, the division of operations between the threads may be changed, or more threads used, when optimising an implementation for the environment in which the clip player is intended to operate.

Figure 9

Figures 9 to *13* contain equations within which the following parameters are used:

SR Skip Rate

NP Next Prefetch frame number

F	Current playback Frame number
SF	Start Frame from which playback commenced
T	Elapsed real time since playback started
FRC	Frame Rate for Clip
TN	Time to transfer last frame over network
D	Number of unread frames in queue
P	Integer value derived from NP
S	Integer value derived from F

The step **812** of prefetching another frame, shown as part of the prefetch thread **701** in *Figure 8*, is detailed in *Figure 9*. At step **901** a frame is prefetched into the next available location of the frame queue **505**. This location is pointed to by the in-pointer **803**, which is automatically incremented as a result of this step. The frame number, or index, is derived from the value NP, **802**, which is a prefetch parameter **506**. When automatic mode is selected, the player generates fractional values of NP, for example 58.932. These fractional values are used so that over several iterations, the fractional parts of the parameters are accumulated and accuracy is not lost. However, when a frame number is required, this must be an integer value, so the frame requested would be frame fifty-eight, which is the integer portion of 58.932.

Once the frame has been prefetched into the frame queue **505**, the value of NP is updated by the prefetch thread at step **902**, by adding the skip rate SR to it. At step **903** a question is asked as to whether a lock request has been made. A lock request can be made by the player thread **702**. When the lock is granted, step **903** continues in a loop, and the player thread is then free to make modifications to a prefetch parameter without causing

interference with any of steps **901** or **902**. For example, the player thread may update the value of NP, which can be done during the loop of step **903** without interfering with the critical operations of steps **901** and **902.** It will then be certain that the value of NP set by the player thread **702** will be used at step **901**. Once any such operations have been completed, the lock is released, and this completes the step **812** for prefetching another frame.

Figure 10

Displaying a next frame at its due time is done at step **821** by the player thread, as shown in *Figure 8*. This step is detailed in *Figure 10*. At step **1001** a calculation is made of the next frame to display, based upon the elapsed real time. This calculation takes into account the frame rate for the clip FRC, which is a frame timing parameter. A second frame timing parameter is also used, SF, the start frame number from which playback commenced, as it is not always the case that playback will start from frame zero. The elapsed real time of playback, T, is used to control the value produced, so that whichever frame is selected from the queue for display, this selection is made in response to the real time; the time experienced by the person looking at the player **301**. The frames that are being fetched from the frame store are not necessarily continuous, and need not even be in order, provided they are fetched before their respective due times for display. The result of the calculation made at step **1001** is a fractional frame value, F.

At step **1002** the queue is examined to find the most recent frame S that satisfies the condition where S is less than or equal to F. Thus it is possible that on several iterations of step **821**, the same frame S will be identified at step **1002**, until enough real time has elapsed to select the next

prefetched frame in the frame queue **505**.

At step **1003** a question is asked as to whether frame S is already on display. If so, there is no need to perform any additional displaying operations. Alternatively, if a different frame now needs to be displayed, control is directed to step **1004**. At this step, data is transferred from the frame queue **505** to the graphics card, for display on the monitor **103**. At step **1005** all frames in the queue having an earlier frame number than frame S, are removed. This is achieved by incrementing the out-pointer **804** to the currently displayed frame, thus making room for one or several new frames to be fetched by the prefetch thread **701**.

Figure 11

Prefetch synchronisation, as performed at step **822** in *Figure 8*, is detailed in *Figure 11*. At step **1101** the prefetch lock is requested. At step **1102** a question is asked as to whether the prefetch lock has been granted. If not, control is directed to step **1101**, alternatively the prefetch lock has been granted and this ensures that the prefetch thread is safely locked in the loop formed at step **903** in *Figure 9*. Thereafter it is safe for the player thread to udpate the prefetch parameters **506**, and control is directed to step **1103**.

At step **1103** a question is asked as to whether the skip rate has been set to “automatic”. This is controlled by the user by the interface component indicated at **309** in *Figure 3*. If the skip rate is not automatic, it will have been set at a fixed rate, for example 2:1, as indicated at step **1104**. A rate of 2:1 is defined by setting the skip rate SR to the value two. Alternatively if the skip rate is automatic, control is directed to step **1105**.

At step **1105** the skip rate is updated in response to the measured rate of image transfer over the network. This results in a fractional value for SR being set, for example 3.137. Once the skip rate has been determined, whether manually or automatically, control is directed to step **1106**. At step **1106** the next frame to prefetch is defined by the value of NP. NP may take a fractional value, as required when the skip rate is set automatically, and this is then converted into an integer at step **901** in *Figure 9*. The next frame to prefetch is calculated with reference to a value D, which defines the number of available unread frames in the queue. For example, if three frames, twenty-two, twenty-four and twenty-six have yet to be displayed, then the next frame to prefetch would be twenty-eight. If the resulting value of NP is less than its previous value, then the previous value is used instead. This may occur if the skip rate changes dramatically as a result in an increase in available network bandwidth.

Step **1106** is a second method of updating the value of NP, the first being performed at step **902**. The results of step **902** are used whenever step **1106** has not had a chance to generate a new value. The calculation performed at step **1106** has the effect of correcting any lead or lag between the in-pointer and out-pointer of the frame queue. Synchronisation of their rate of progression through the queue is achieved by automatically calculating the skip rate at step **1105**. When the skip rate has been set to a fixed value, then the calculation performed at step **1106** will ensure that the player still performs at a reasonable level of efficiency.

At step **1107**, the prefetch lock is released, thus enabling both threads **701** and **702** to continue their execution independently.

Figure 12

The derivation of relationships used in step **1105**, in which the skip rate is updated automatically, is detailed in *Figure 12*. The time for the most recent image frame to download from the network provides a measure of the network capacity. In its simplest form, the skip rate, SR, is given by the product of the frame rate for the clip, FRC, and the time, TN, required to download the last frame. However, a safety margin can be applied, to avoid using up all the available network capacity for a player on one particular workstation. In the preferred embodiment this is set to a value of 1.2, although other values, depending upon experiment, may also be chosen to optimise performance for several users on the network. The rate of data transfer over the network may vary considerably from frame to frame, and so an average of several measurements is used. A low pass filter to achieve this is shown at **1201** in *Figure 12*. In an alternative embodiment, an adaptive statistical model is used to predict the likely transfer bandwidth over the network, based upon several statistical variables generated from previous measurements of the time taken to download a frame.

Figure 13

Updating the skip rate automatically, performed at step **1105** in *Figure 11*, is detailed in *Figure 13*. At step **1301** a question is asked as to whether this is the first iteration of the skip rate calculation. If so, control is directed to step **1302**, where the skip rate is calculated without reference to previous values. Alternatively, control is directed to step **1303**, where the previous value for SR is included in the new calculation of SR, resulting in the filtering

effect. Steps **1302** and **1303** may be replaced with an adaptive statistical model in an alternative embodiment.

The invention enables high bandwidth clips to be viewed over a low bandwidth network by skipping frames. The clip completes playback in its correct time, with the only distortion being in the form of a lack of smoothness as frames are skipped. The events depicted by the clip are not speeded up or slowed down. The skip rate may be modified automatically, either by updating a next frame to fetch, NP, and or by modifying a skip rate, SR, or other parameter that achieves the same effect.

The steps that are performed include:

(a) selecting a next frame for preloading by skipping at least one frame in the clip's sequence, as performed at step **902** and or step **1106**;

(b) preloading a next frame from a frame source into a queue of frames **505**, as performed at step **901**;

(c) displaying a preloaded frame at its due time, as performed at step **821**;

(d) processing elapsed real time T since the clip started playing with a frame timing parameter, for example as performed at step **1001**, in which the frame timing parameter is FRC, the frame rate of the clip; and

(e) updating the number of frames to skip in response to step (d), as performed at step **1105** or step **1106**.

As these steps are repeated, and implemented preferably in the form of multiple concurrent threads, their order is not necessarily important. It will be understood by those skilled in the art, that implementation can be varied considerably, in order to achieve the best effect within the specific system in which the invention is to be deployed.

Claims

1. Apparatus for viewing image data, comprising display means, processing means and network connecting means for transferring frames of said image data over a network from a remotely connected frame source;

said image data comprises a plurality of image frames, and has a frame rate from which may be inferred a due time for display of each frame in a sequence of frames in said image data;

said frame source returns a frame in response to a frame request issued over said network; wherein

said processing means is configured to play a clip by:

displaying selected frames from said frame source, on said display means, at their due time; and

skipping frames in said frame sequence in response to an indication of the data transfer rate of said network.

2. Apparatus according to claim **1**, wherein said indication of the data transfer rate is provided by a comparison of the relative position of an input and an output pointer in a queue of frames that have been selected for display.

3. Apparatus according to claim **1**, wherein said frame source includes means for storing pre-rendered image frames.

4. Apparatus according to claim 1, wherein said frames are skipped in response to a prediction of a network data transfer rate.

5. Apparatus according to claim **1**, wherein frames are prefetched into a frame queue prior to their due time.

6. Apparatus according to claim **1**, wherein a frame skip rate is defined by a user.

7. Apparatus according to claim **1**, wherein a frame is selected for display by processing its due time with elapsed real time since playback started.

8. Apparatus for displaying image data, comprising display means, processing means, memory means and network connecting means for enabling transfer of image data over a network from a frame source remotely connected to said network, in which:

said image data comprises a plurality of image frames, sequences of said frames being organised into clips, each clip having a frame rate, and each frame in a clip thereby having a due time for display with respect to a start time for playing the clip; wherein

said processing means is configured to perform operations to play a clip from said frame source by repeating steps of:

(a) selecting a next frame for preloading by skipping at least one frame in the clip's frame sequence;

(b) preloading a frame from said frame source into a frame queue in said memory means;

(c) displaying a preloaded frame at its due time;

(d) processing elapsed real time since the clip started playing with a frame timing parameter; and

(e) updating the number of frames to skip in response to said processing step (d).

9. Apparatus according to claim **8**, wherein said frame timing parameter is the due time for a frame.

10. Apparatus according to claim **8**, wherein instructions for steps (a) to (e) are executed as multiple threads.

11. A method of displaying image data on an image viewing station that comprises display means, processing means and network connecting means for transferring frames of said image data over a network from a remotely connected frame source;

said image data comprises a plurality of image frames, and has a frame rate from which may be inferred a due time for display of each frame in a sequence of frames in said image data;

said frame source returns a frame in response to a frame request issued over said network; wherein

said processing means is configured to play a clip in which said method includes:

displaying selected frames from said frame source, on said display means, at their due time; and

skipping frames in said frame sequence in response to an indication of the data transfer rate of said network.

12. A method according to claim **11**, wherein said indication of the data transfer rate is provided by a comparison of the relative position of an input and an output pointer in a queue of frames that have been selected for display.

13. A method according to claim **11**, wherein said frame source includes means for storing pre-rendered image frames.

14. A method according to claim **11**, wherein said frames are skipped in response to a prediction of a network data transfer rate.

15. A method according to claim **11**, wherein frames are prefetched into a frame queue prior to their due time.

16. A method according to claim **11**, wherein a frame skip rate is defined by a user.

17. A method according to claim **11**, wherein a frame is selected for display by processing its due time with elapsed real time since playback started.

18. A method for displaying image data on an image viewing station that comprises display means, processing means, memory means

and network connecting means for enabling transfer of image data over a network from a frame source remotely connected to said network, in which:

said image data comprises a plurality of image frames, sequences of said frames being organised into clips, each clip having a frame rate, and each frame in a clip thereby having a due time for display with respect to a start time for playing the clip; wherein

said processing means is configured to perform operations to play a clip from said frame source by a method comprising repeated steps of:

(a) selecting a next frame for preloading by skipping at least one frame in the clip's frame sequence;

(b) preloading a frame from said frame source into a frame queue in said memory means;

(c) displaying a preloaded frame at its due time;

(d) processing elapsed real time since the clip started playing with a frame timing parameter; and

(e) updating the number of frames to skip in response to said processing step (d).

19. A method according to claim **18**, wherein said frame timing parameter is the due time for a frame.

20. A method according to claim **18**, wherein instructions for steps (a) to (e) are executed as multiple threads.

21. A data structure upon a machine readable medium, comprising instructions for controlling an image viewing system to perform steps for

viewing image data, said viewing system comprising:

display means, processing means and network connecting means for transferring frames of said image data over a network from a remotely connected frame source;

said image data comprising a plurality of image frames, and has a frame rate from which may be inferred a due time for display of.each frame in a sequence of frames in said image data;

said frame source returns a frame in response to a frame request issued over said network; wherein

said processing means being configurable by said instructions to play a clip in which said method includes:

displaying selected frames from said frame source, on said display means, at their due time; and

skipping frames in said frame sequence in response to an indication of the data transfer rate of said network.

22. A data structure according to claim **21**, wherein said indication of the data transfer rate is provided by a comparison of the relative position of an input and an output pointer in a queue of frames that have been selected for display.

23. A data structure according to claim **21**, wherein said frame source includes means for storing pre-rendered image frames.

24. A data structure according to claim **21**, wherein said frames are skipped in response to a prediction of a network data transfer rate.

25. A data structure according to claim **21**, wherein frames are prefetched into a frame queue prior to their due time.

26. A data structure according to claim **21**, wherein a frame skip rate is defined by a user.

27. A data structure according to claim **21**, wherein a frame is selected for display by processing its due time with elapsed real time since playback started.

18. A data structure upon a machine readable medium, comprising instructions for controlling an image viewing system to perform steps for viewing image data, said viewing system comprising:

display means, processing means, memory means and network connecting means for enabling transfer of image data over a network from a frame source remotely connected to said network, in which:

said image data comprises a plurality of image frames, sequences of said frames being organised into clips, each clip having a frame rate, and each frame in a clip thereby having a due time for display with respect to a start time for playing the clip; wherein

said processing means is configured to perform operations to play a clip from said frame source by a method comprising repeated steps of:

(a) selecting a next frame for preloading by skipping at least one frame in the clip's frame sequence;

(b) preloading a frame from said frame source into a frame queue in said memory means;

(c) displaying a preloaded frame at its due time;

(d) processing elapsed real time since the clip started playing with a frame timing parameter; and

(e) updating the number of frames to skip in response to said processing step (d).

29. A data structure according to claim **28**, wherein said frame timing parameter is the due time for a frame.

30. A data structure according to claim **28**, wherein instructions for steps (a) to (e) will be executed as multiple threads.

Abstract of the Disclosure

Displaying Image Data

A method of viewing a clip of image data stored (**109**) remotely on a network (**106**). The viewing is performed by an image processing station (**101**) connected to the network. Frames of a clip are prefetched (**701**) and certain of the frames in a frame sequence are skipped, in alternation with frames that are fetched. Frames are skipped to compensate for network conditions. Display (**702**) of the prefetched frames is performed by selecting (**1001**) a prefetched frame for display appropriate to the elapsed real time since playback started. The clip is viewed in real time, even though the network (**106**) does not necessarily support the data transfer rate required for full playback of the clip.

(Figure 8)

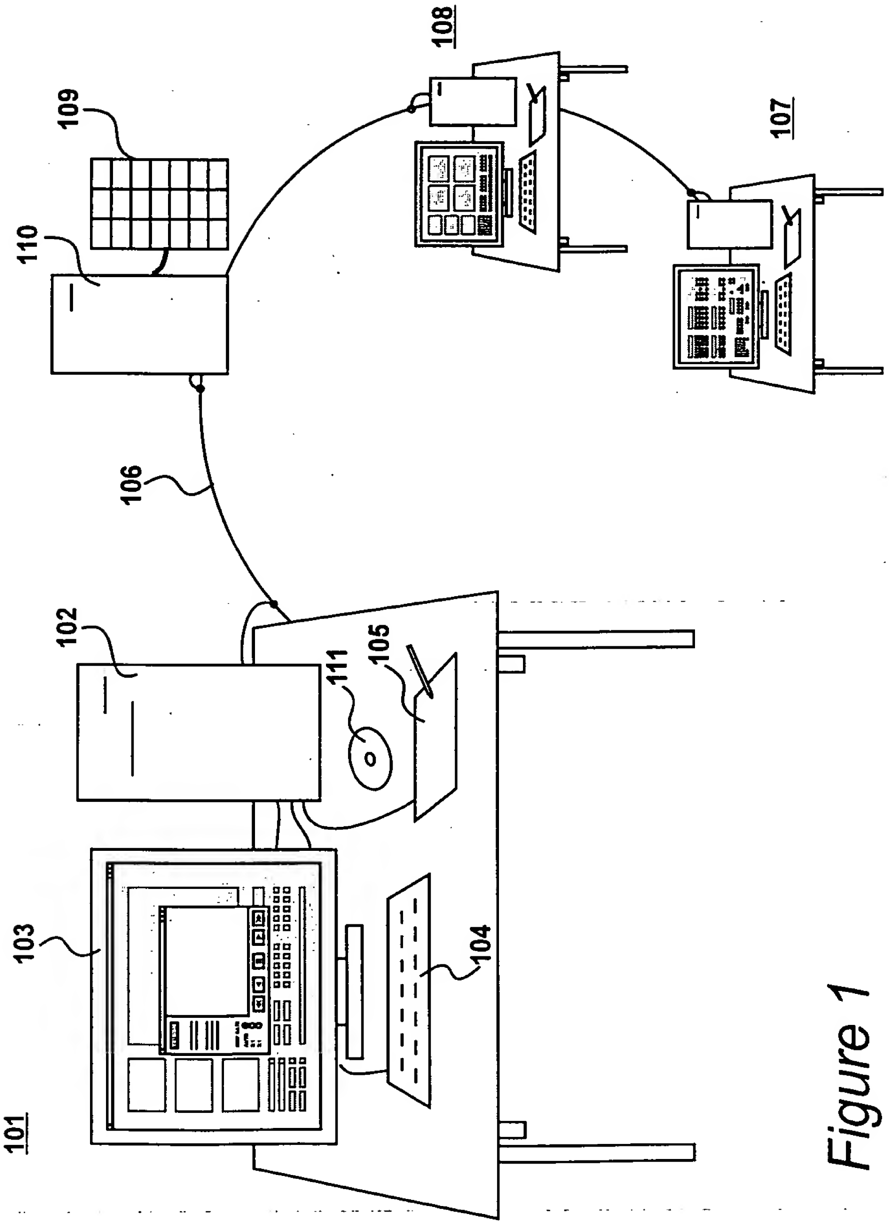

Figure 1

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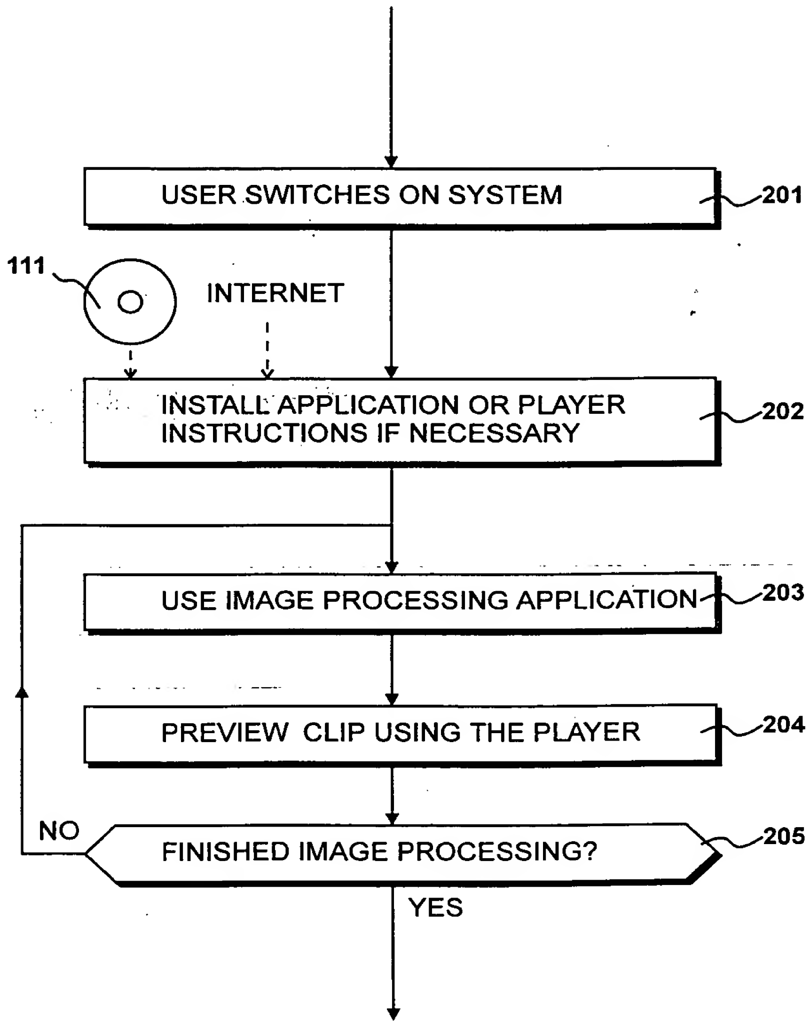
USER SWITCHES ON SYSTEM
201
111
INTERNET
INSTALL APPLICATION OR PLAYER INSTRUCTIONS IF NECESSARY
202
USE IMAGE PROCESSING APPLICATION
203
PREVIEW CLIP USING THE PLAYER
204
NO
FINISHED IMAGE PROCESSING?
205
YES

Figure 2

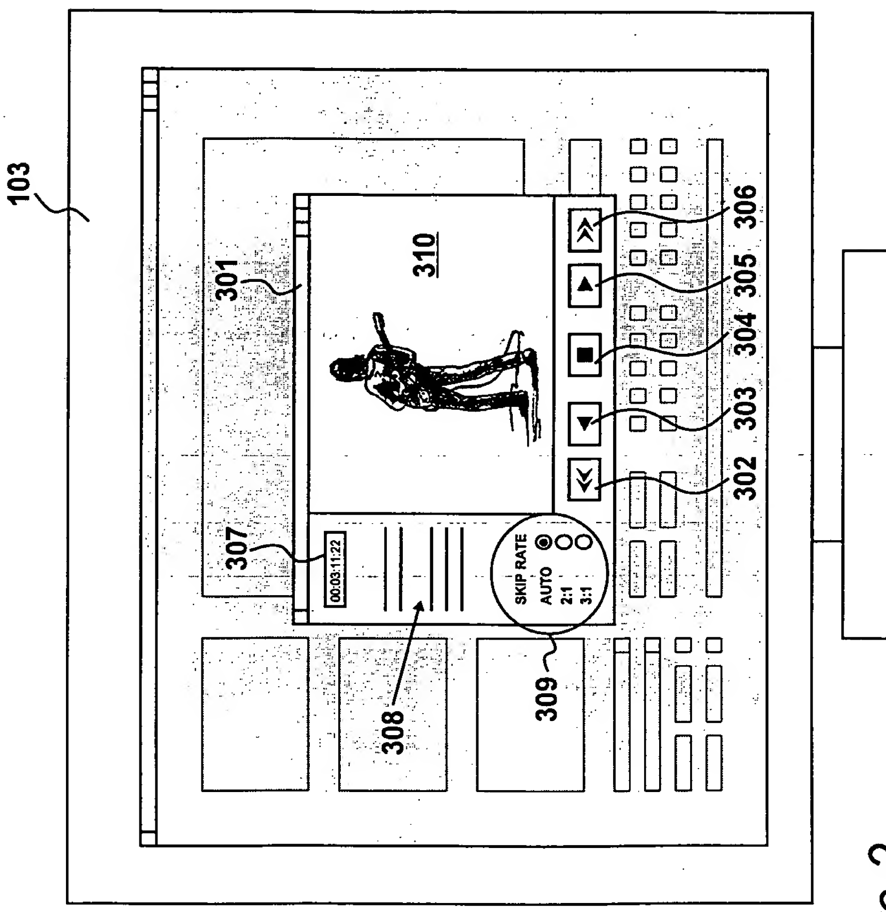
103
301
302
303
304
305
306
307
308
309
310
00:03:11:22
SKIP RATE
AUTO
2:1
3:1

Figure 3

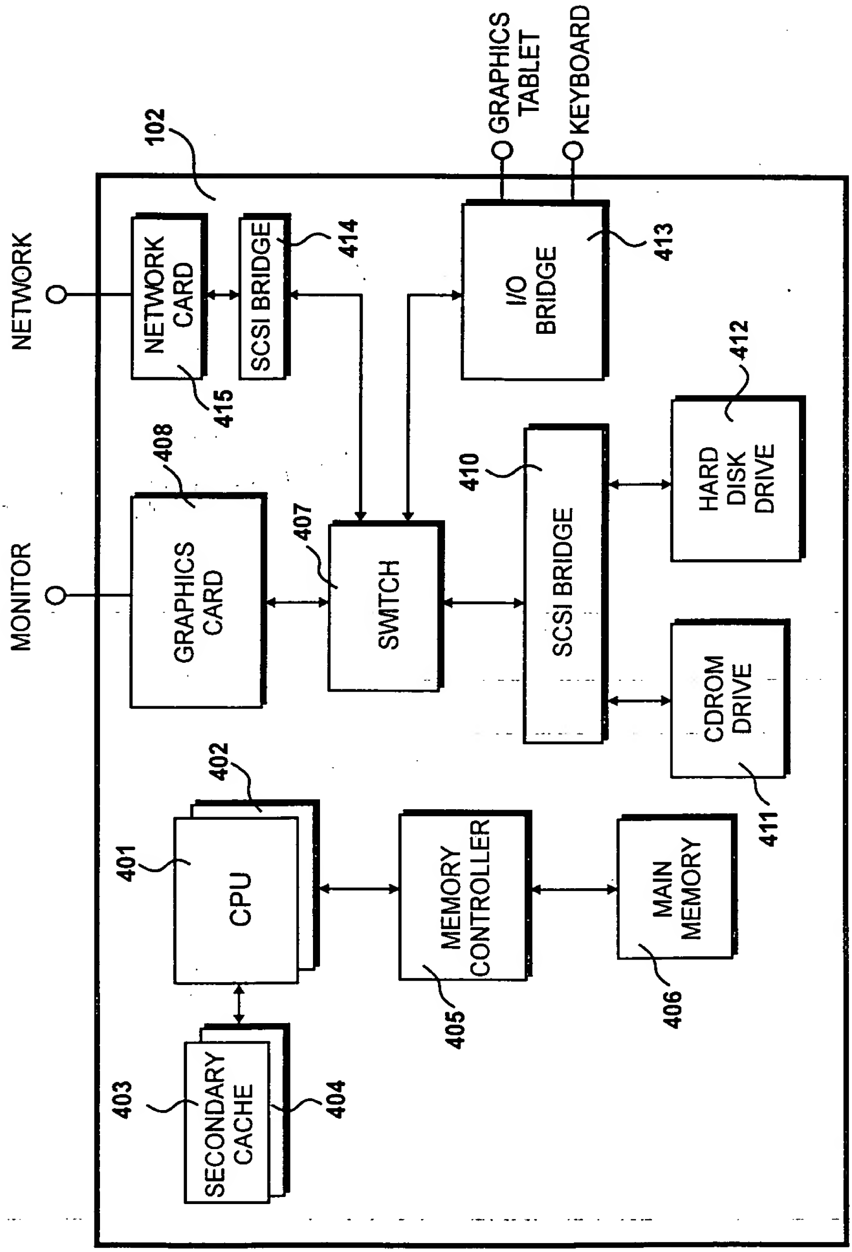
102
NETWORK
NETWORK CARD
SCSI BRIDGE
414
415
GRAPHICS TABLET
KEYBOARD
I/O BRIDGE
413
MONITOR
GRAPHICS CARD
408
407
SWITCH
410
SCSI BRIDGE
HARD DISK DRIVE
412
CDROM DRIVE
411
402
401
CPU
MEMORY CONTROLLER
405
MAIN MEMORY
406
403
SECONDARY CACHE
404

Figure 4

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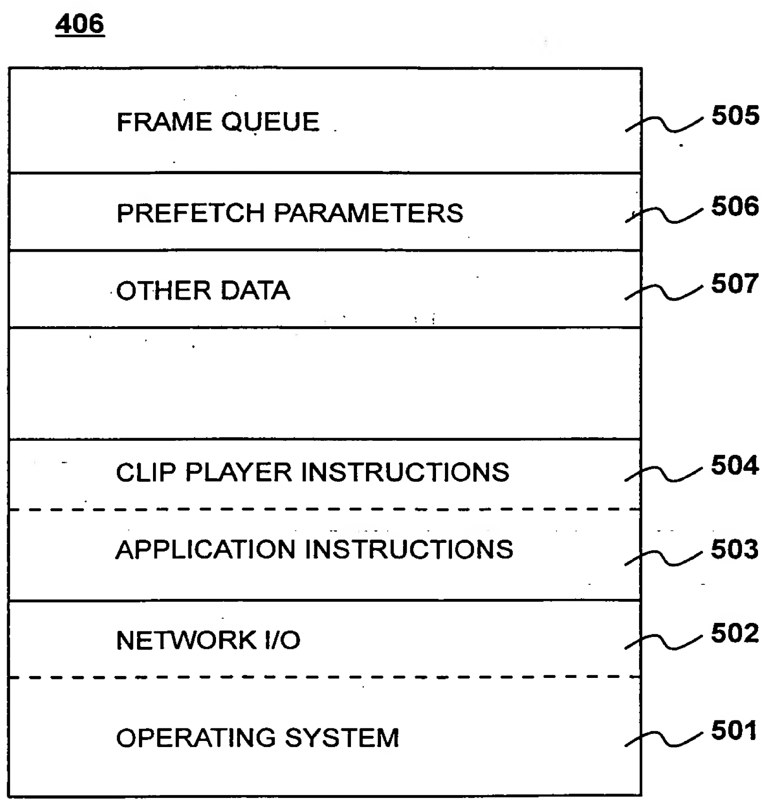
406
FRAME QUEUE
505
PREFETCH PARAMETERS
506
OTHER DATA
507
CLIP PLAYER INSTRUCTIONS
504
APPLICATION INSTRUCTIONS
503
NETWORK I/O
502
OPERATING SYSTEM
501

Figure 5

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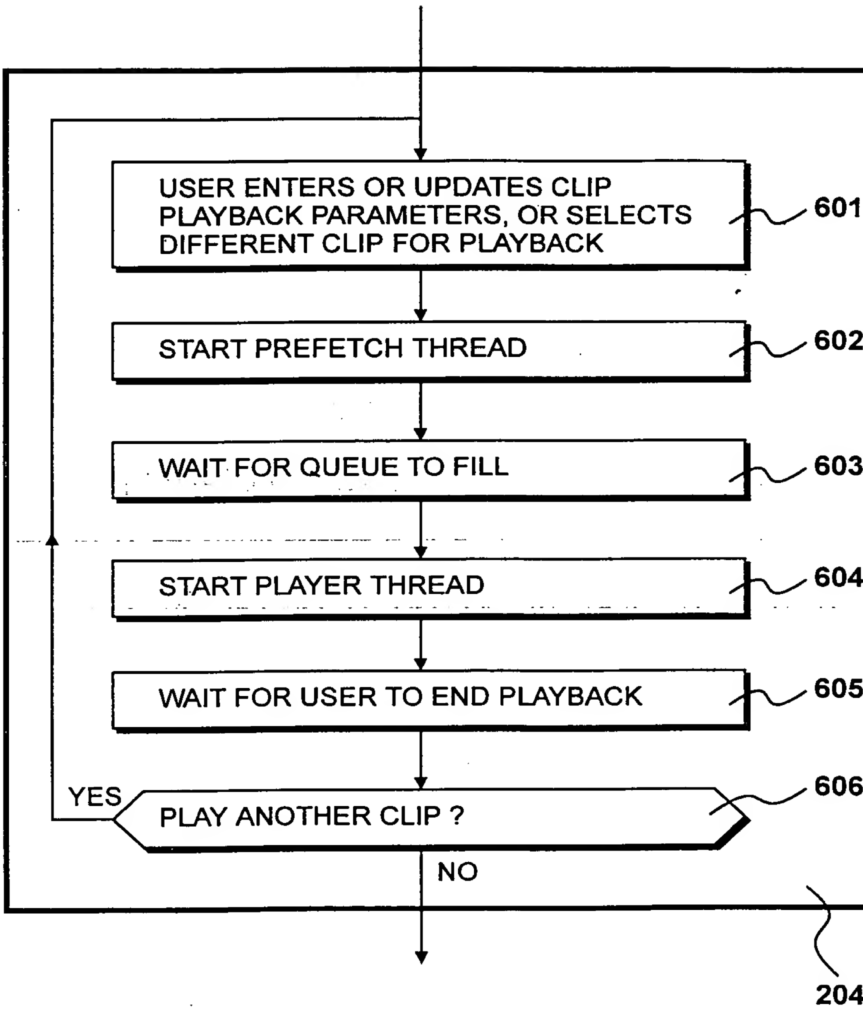

USER ENTERS OR UPDATES CLIP PLAYBACK PARAMETERS, OR SELECTS DIFFERENT CLIP FOR PLAYBACK
601
START PREFETCH THREAD
602
WAIT FOR QUEUE TO FILL
603
START PLAYER THREAD
604
WAIT FOR USER TO END PLAYBACK
605
PLAY ANOTHER CLIP ?
606
YES
NO
204

Figure 6

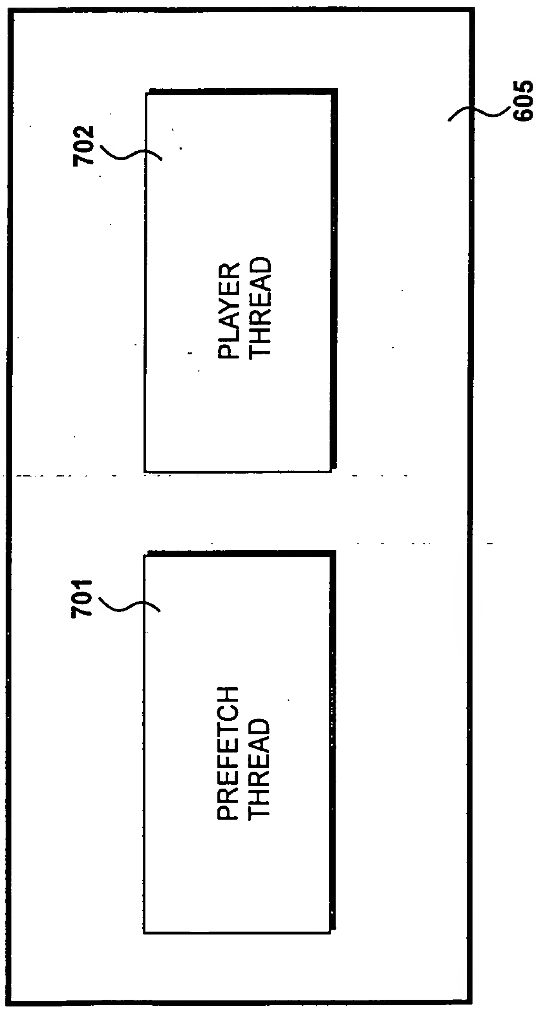


Figure 7

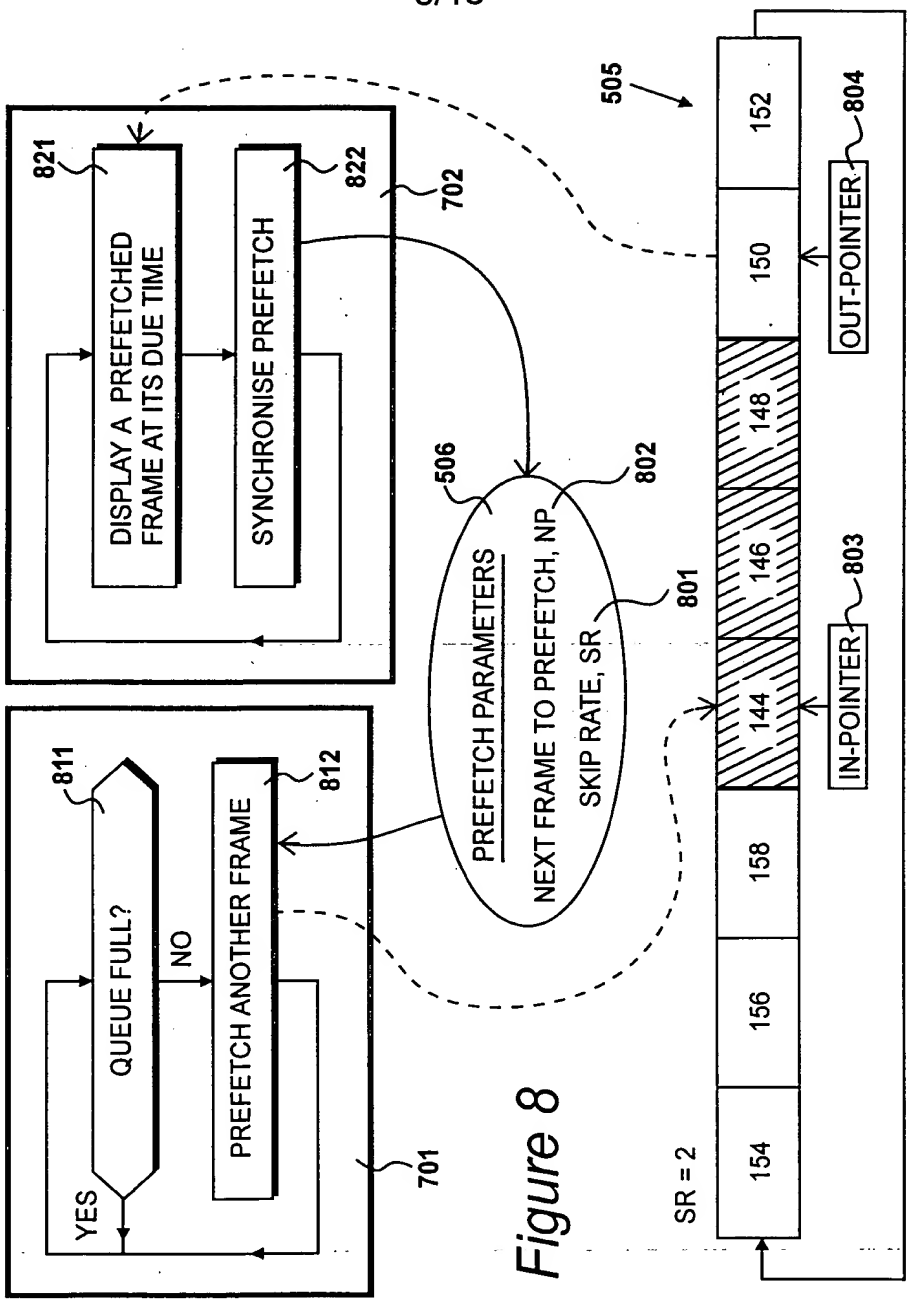

505
152
150
148
146
144
158
156
154
OUT-POINTER
804
IN-POINTER
803
SR = 2
702
821
DISPLAY A PREFETCHED FRAME AT ITS DUE TIME
822
SYNCHRONISE PREFETCH
506
PREFETCH PARAMETERS
NEXT FRAME TO PREFETCH, NP
SKIP RATE, SR
802
801
701
811
QUEUE FULL?
YES
NO
812
PREFETCH ANOTHER FRAME

Figure 8

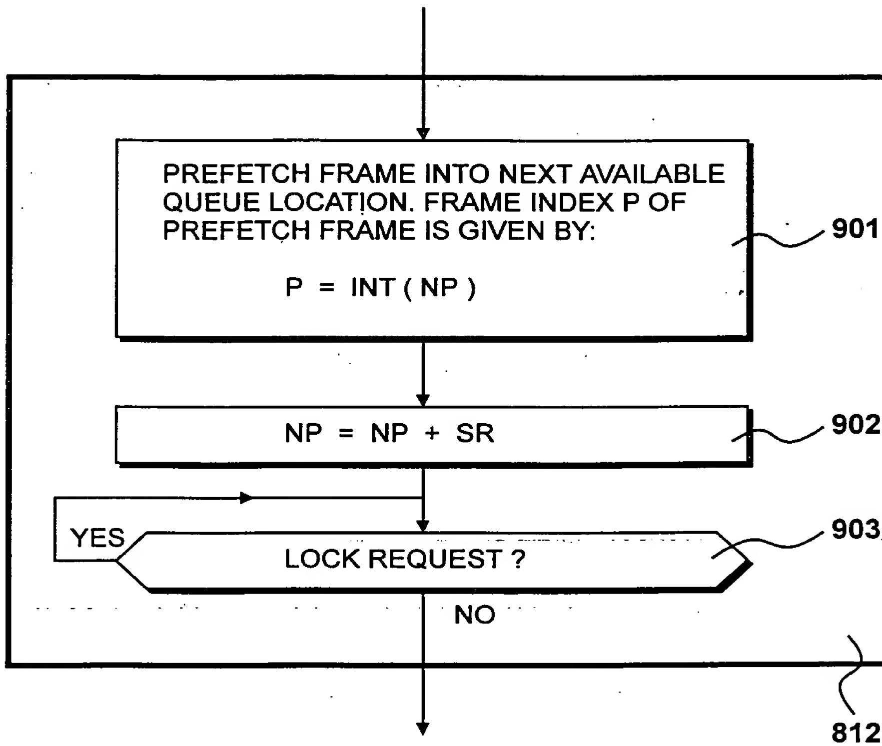
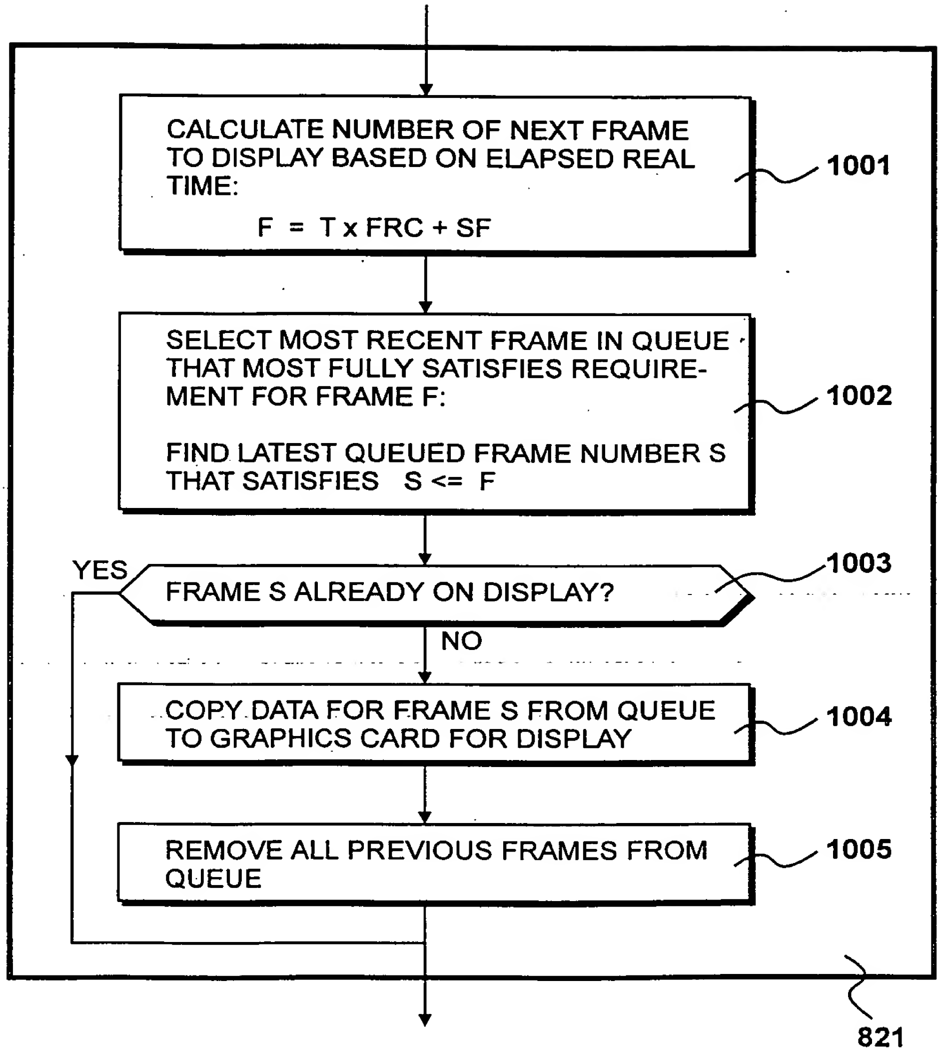


Figure 9

P = Integer index of next frame to prefetch
NP = Non-integer index of next frame to prefetch
SR = Skip rate



F = Current playback frame number
T = Elapsed real time since clip started playing
FRC = Frame rate for clip
SF = Start frame from which playback commenced
S = Frame selected for display to most fully satisfy requirement for frame F

Figure 10

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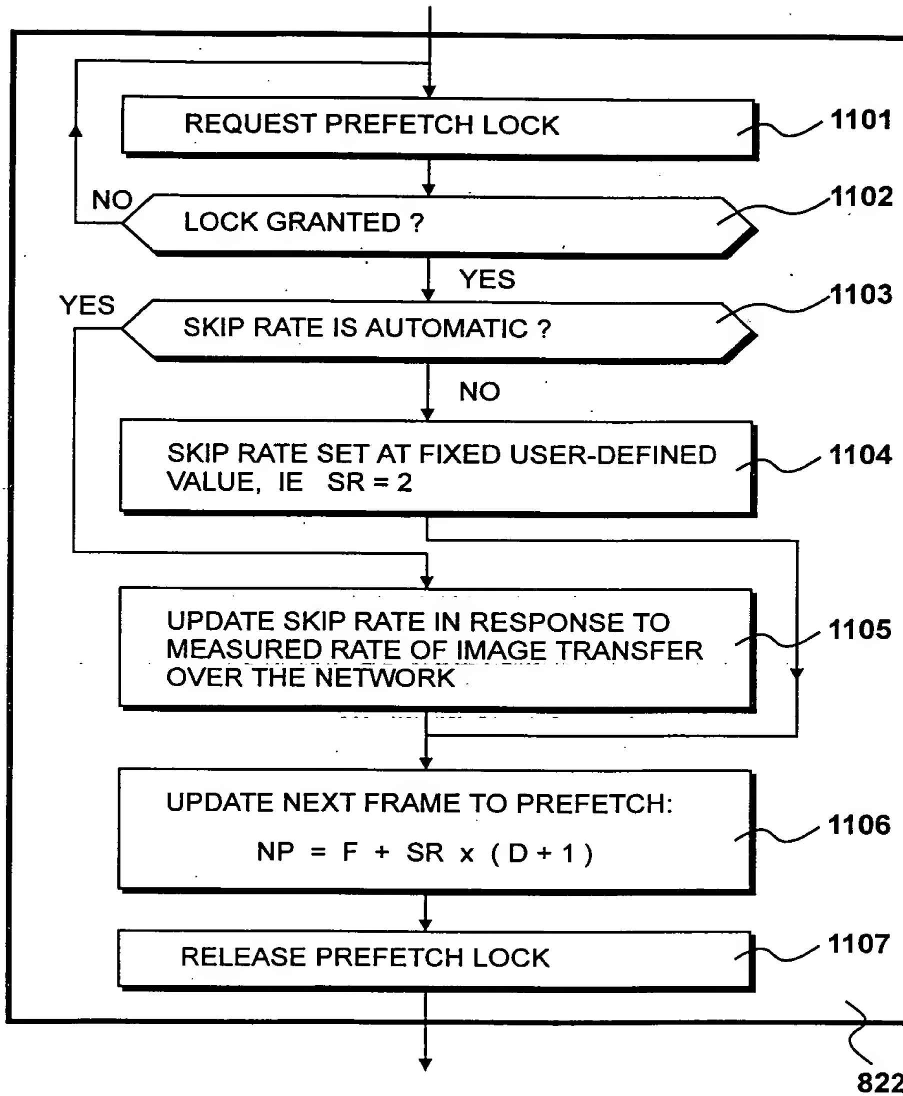

SR = Skip rate
NP = Next prefetch frame number
F = Current playback frame number
D = Number of unread frames in queue

Figure 11

IF TN = THE AMOUNT OF TIME TAKEN TO TRANSFER THE MOST RECENT IMAGE OVER THE NETWORK (IN SECONDS), THEN

THE RATE OF NETWORK TRANSFER, RN, IS GIVEN BY:

$$RN = \frac{1}{TN}$$

THE SKIP RATE IS THE RATIO OF THE FRAME RATE OF THE CLIP, FRC, TO THE ACHIEVABLE RATE, RN, OF FRAME TRANSFER OVER THE NETWORK:

$$SR = \frac{FRC}{RN}$$

AND THEREFORE:

$$SR = FRC \times TN$$

WITH A SAFETY MARGIN:

$$SR = FRC \times TN \times 1.2$$

AND WITH A LOW PASS FILTER:

1201

$$SR = 0.75\,(FRC \times TN \times 1.2) + 0.25 \times SR$$

Figure 12

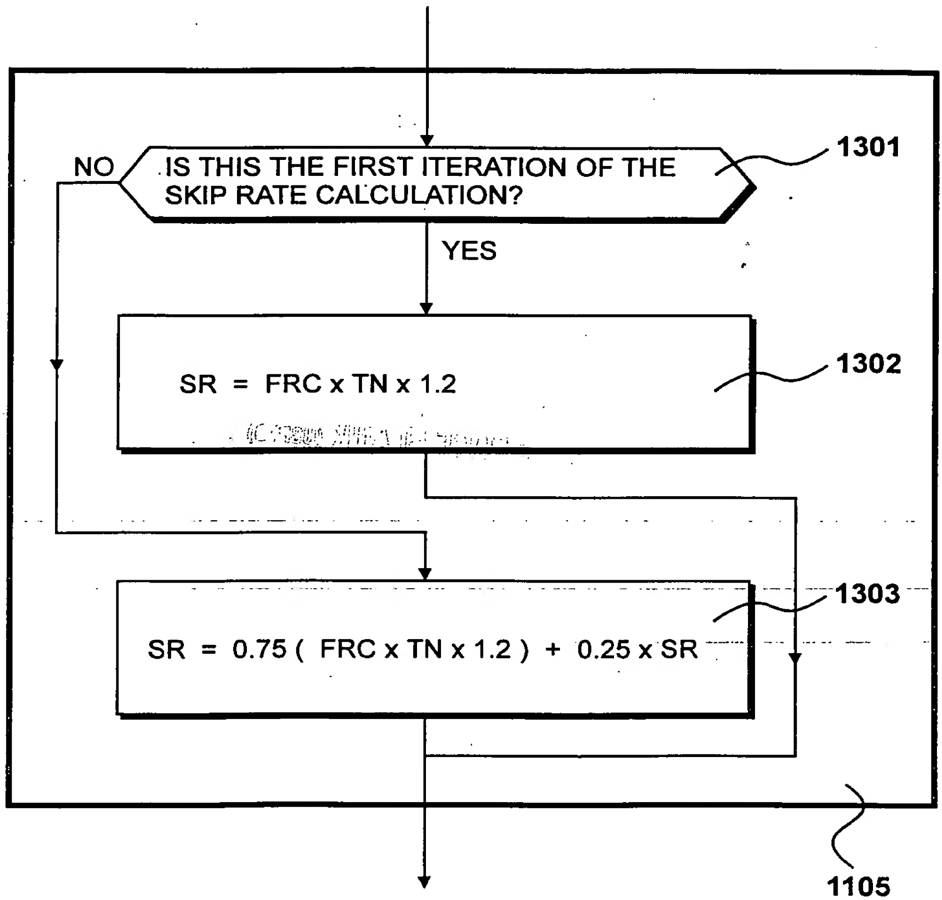

Figure 13

SR = Skip rate
FRC = Clip frame rate
TN =Time to transfer most recent frame over the network

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